2015 NREL Photovoltaic (PV) Solar Resource Workshop

Practical Issues with Quantifying Solar Resource for PV Systems

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February 27, 2015

Acknowledgements

Kathleen E. Moore, Ph.D, iedat
Mark Blohnquist, Apogee Instruments
Jobie Carlisle, Utah Climate Center
Bart Kneff, Campbell Scientific Inc
Jonathan Wright, Met Spec Ltd

GroundWork Met Equipment and Services

Development or pre-construction
Plant build and acceptance testing
Operations and maintenance (O&M)
Asset turnover

GroundWork Services

- System Design and Submittals
- Equipment Supply, Fabrication and Testing
- Installation and Commissioning
- GroundWatch™ Data Quality Program
- Rapid Response Field Work
- Solar Resource Assessments through Clean Power Research
- Program and Fleet Management

Practical Issues for Quantifying Solar Resource

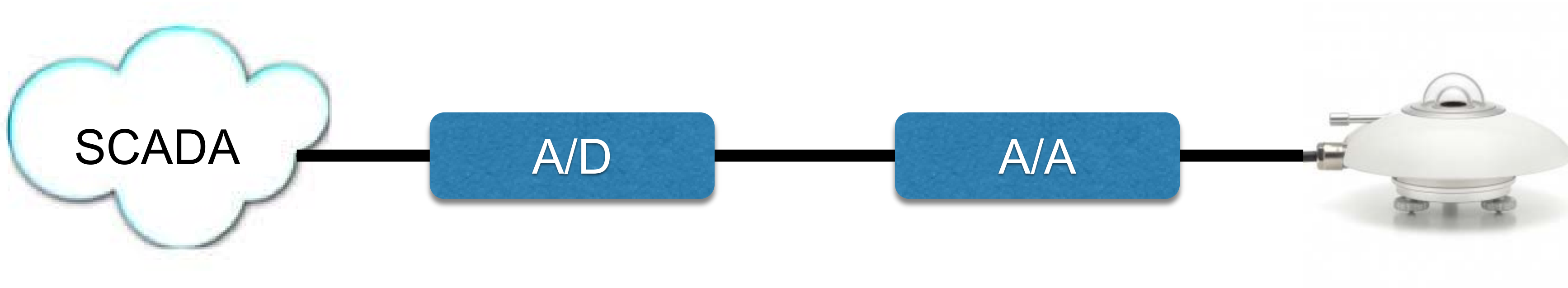
- System Accuracy
- Pyranometer Azimuth, Tilt, and Level
- Siting Within Solar Plant
- Ongoing O&M and Data Review
- Ambient Temperature

Pyranometer specification list				
Ref. no.	Specification	Pyranometer category		
		Secondary standard	first class	second class
1	Response time (time for 95% response)	< 15 s	< 30 s	< 60 s
2	Zero offsets response to 200 W/m² net thermal radiation response to 5 K/hr temperature change	< 7 W/m² < 2 W/m²	< 15 W/m² < 4 W/m²	< 30 W/m² < 8 W/m²
3a	Non-stability (percentage change in responsitivity per year)	< 0.8 %	< 1.5 %	< 3 %
3b	Non-linearity (due to change in irradiance within 100 to 1000 W/m²)	< 0.5 %	< 1 %	< 3 %
3c	Directional response	< 10 W/m²	< 20 W/m²	< 30 W/m²
3d	Spectral selectivity	< 3 %	< 5 %	< 10 %
3e	Temperature response	< 2 %	< 4 %	< 8 %
3f	Tilt response	< 0.5 %	< 2 %	< 5 %

http://kippzonen-blog.nl

System Accuracy

Must account for all contributions to measurement accuracy
Estimate accuracy: square root of the sum of squares



System Accuracy Example

Analog to Analog Converter

Voltage Input: +/-0.1% = 2.9 W/m2

Current Output: +/-0.1 % = 2.9 W/m2

Analog to Digital Converter

Voltage Input: +/-0.07% = 2.03 W/m2

Pyranometer

Hourly: 2% = 22.3 W/m2 (ISO 9060)

Azimuth, Tilt, & Level

- Proper azimuth, tilt, and level critical to accurate irradiance
- Significant issues with proper azimuth alignment of POA pyranometers
- Accurate alignment with compass difficult
- Most technicians not equipped with accurate inclinometers

Azimuth, Tilt, & Level

Verify tilt and level with two-axis inclinometer

Verify azimuth with Magnetometer

Low cost

Easily integrated

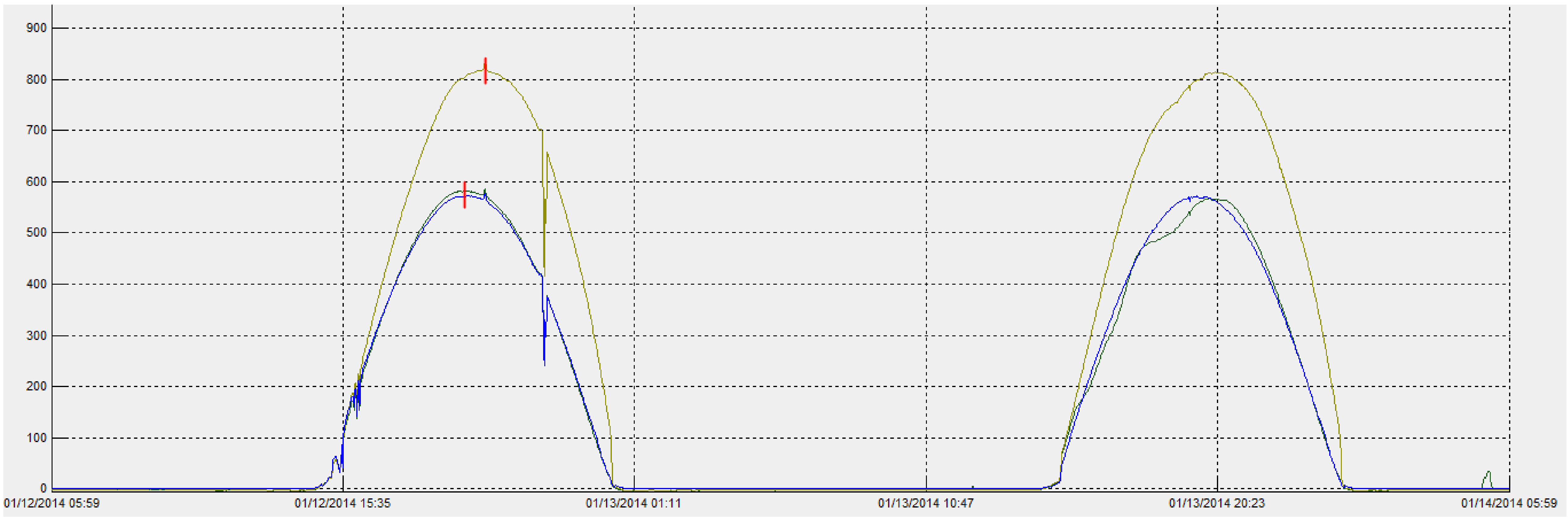
Bracket orientation only

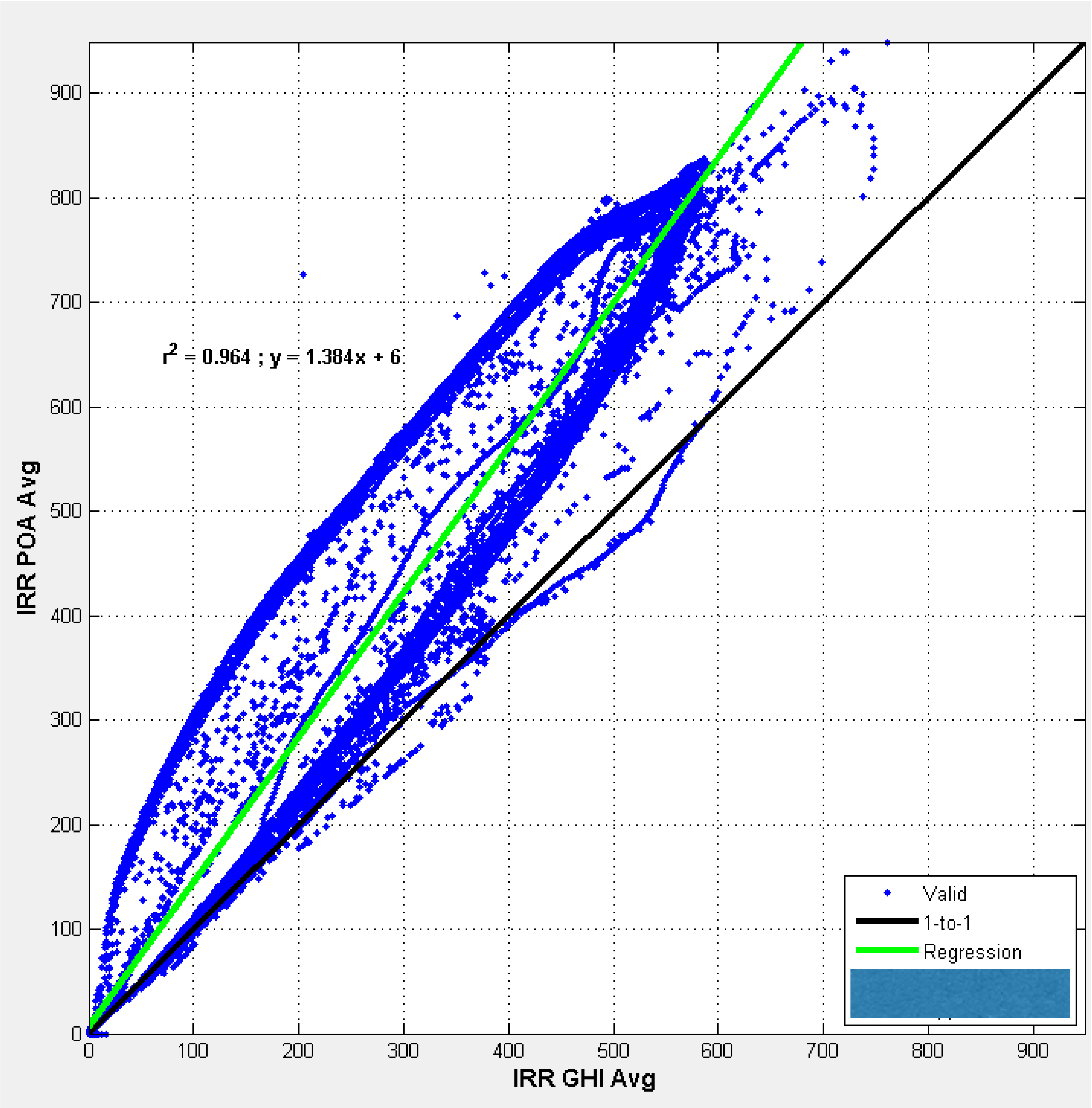
Option to embed in the pyranometer


43°

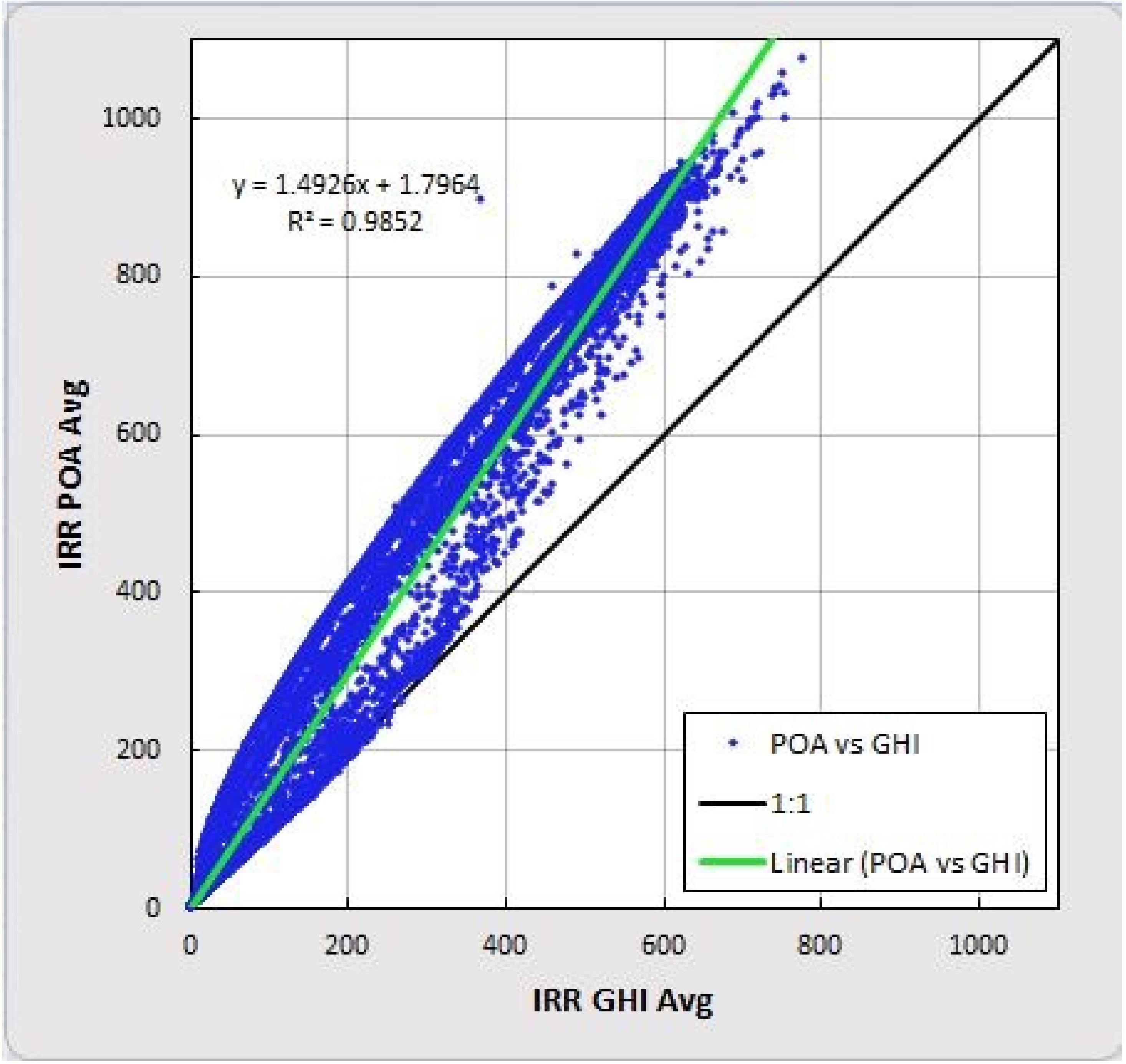
≠

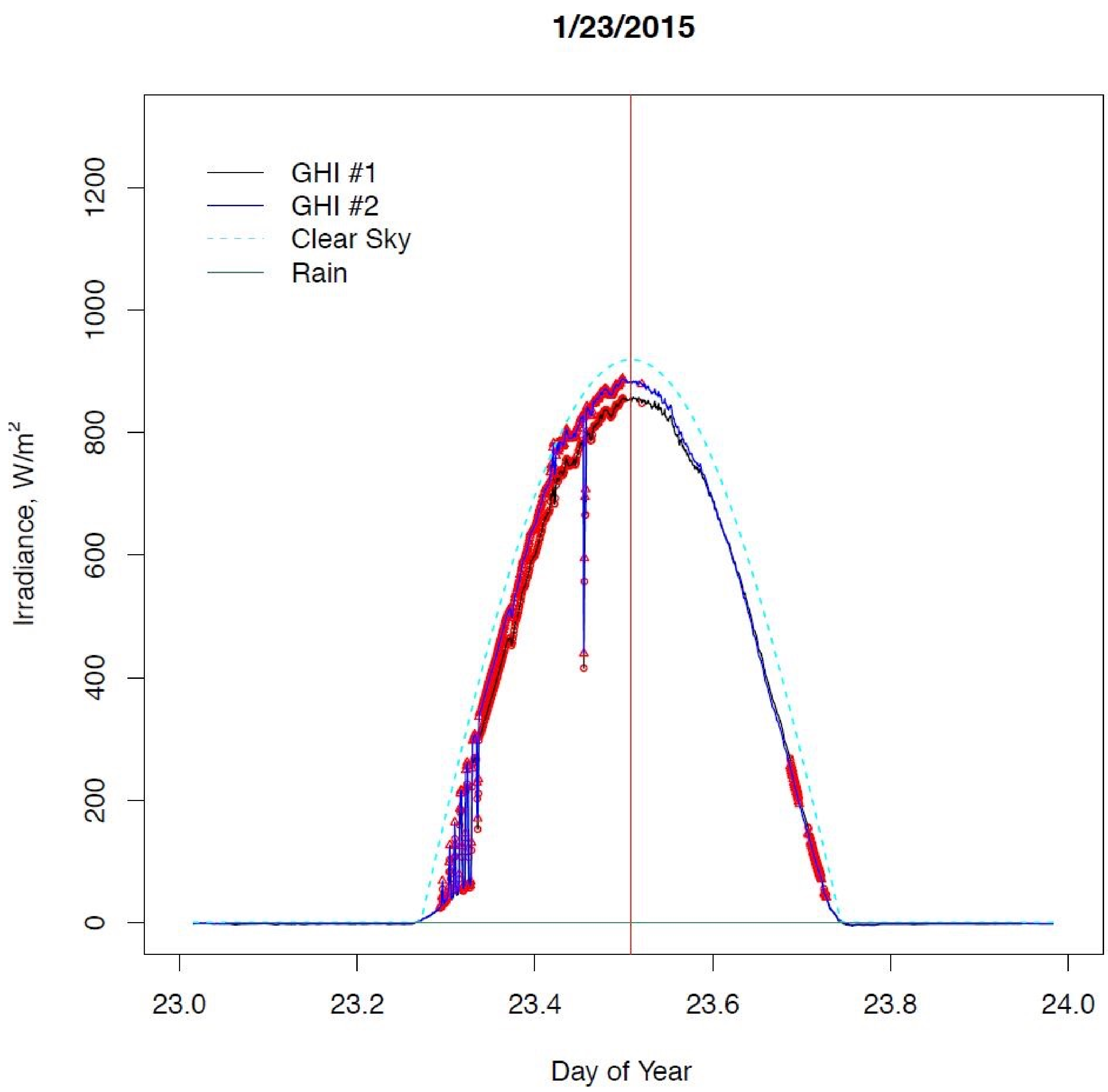

HUSKY
Hold
On/Cal/Off
Reset


900
800
700
600
500
400
300
200
100
0
01/12/2014 05:59
01/12/2014 15:35
01/13/2014 01:11
01/13/2014 10:47
01/13/2014 20:23
01/14/2014 05:59



900
800
700
600
500
400
300
200
100
0
IRR POA Avg
0
100
200
300
400
500
600
700
800
900
IRR GHI Avg
r2 = 0.964 ; y = 1.384x + 6
Valid
1-to-1
Regression


y = 1.4926x + 1.7964
R² = 0.9852
IRR POA Avg
IRR GHI Avg
0
200
400
600
800
1000
POA vs GHI
1:1
Linear (POA vs GHI)


1/23/2015
GHI #1
GHI #2
Clear Sky
Rain
Irradiance, W/m²
0
200
400
600
800
1000
1200
23.0
23.2
23.4
23.6
23.8
24.0
Day of Year

Siting Considerations: Plant Design

- Design plant to reduce field uncertainty of irradiance and met data
- Minimize GPOA pyranometer cable lengths
- Reduce EMF exposure
- Avoid albedo and reflections on pyranometers
- Design station for frequent pyranometer cleaning and leveling

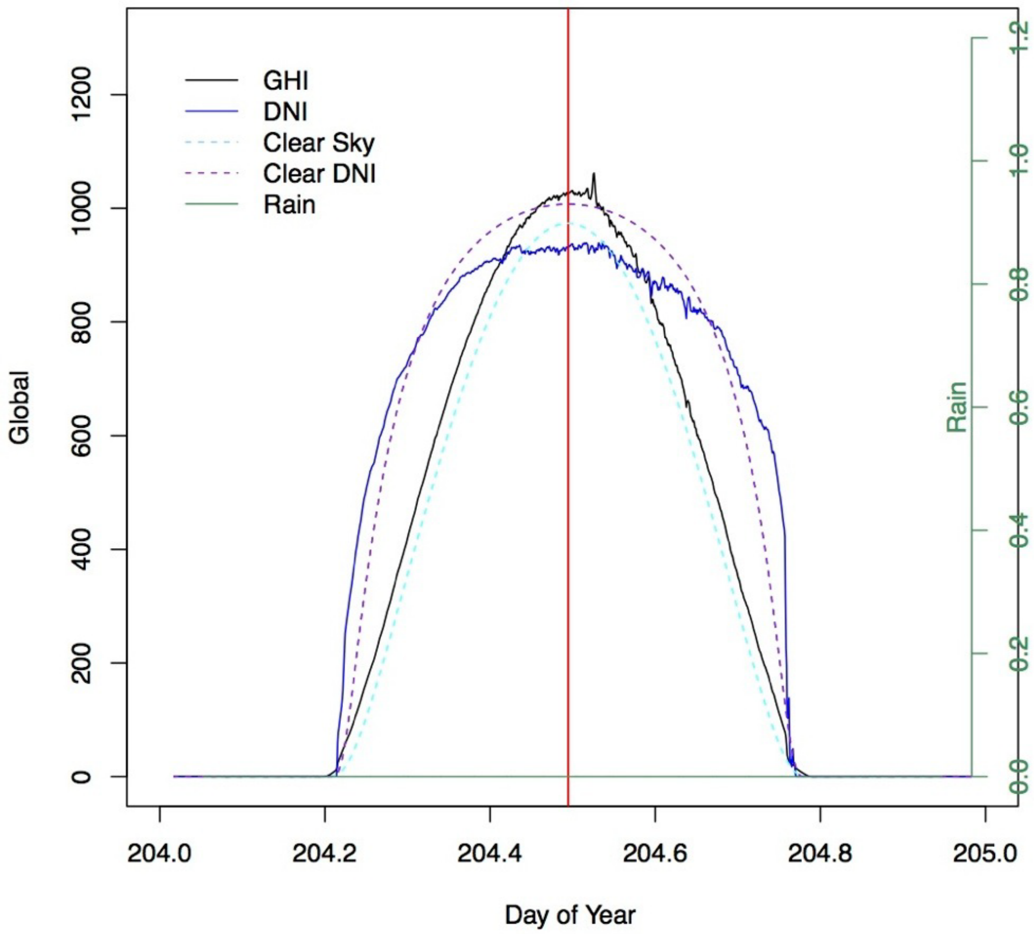
Siting Considerations: Pyranometer Cable Length

High noise environment
Voltage drop negligible
uV output signal
Cable acts as antenna
EMF
Use shielded cable with drain
60 Hz signal conditioning
Over sample and average


courtesy Swinerton Renewable Energy

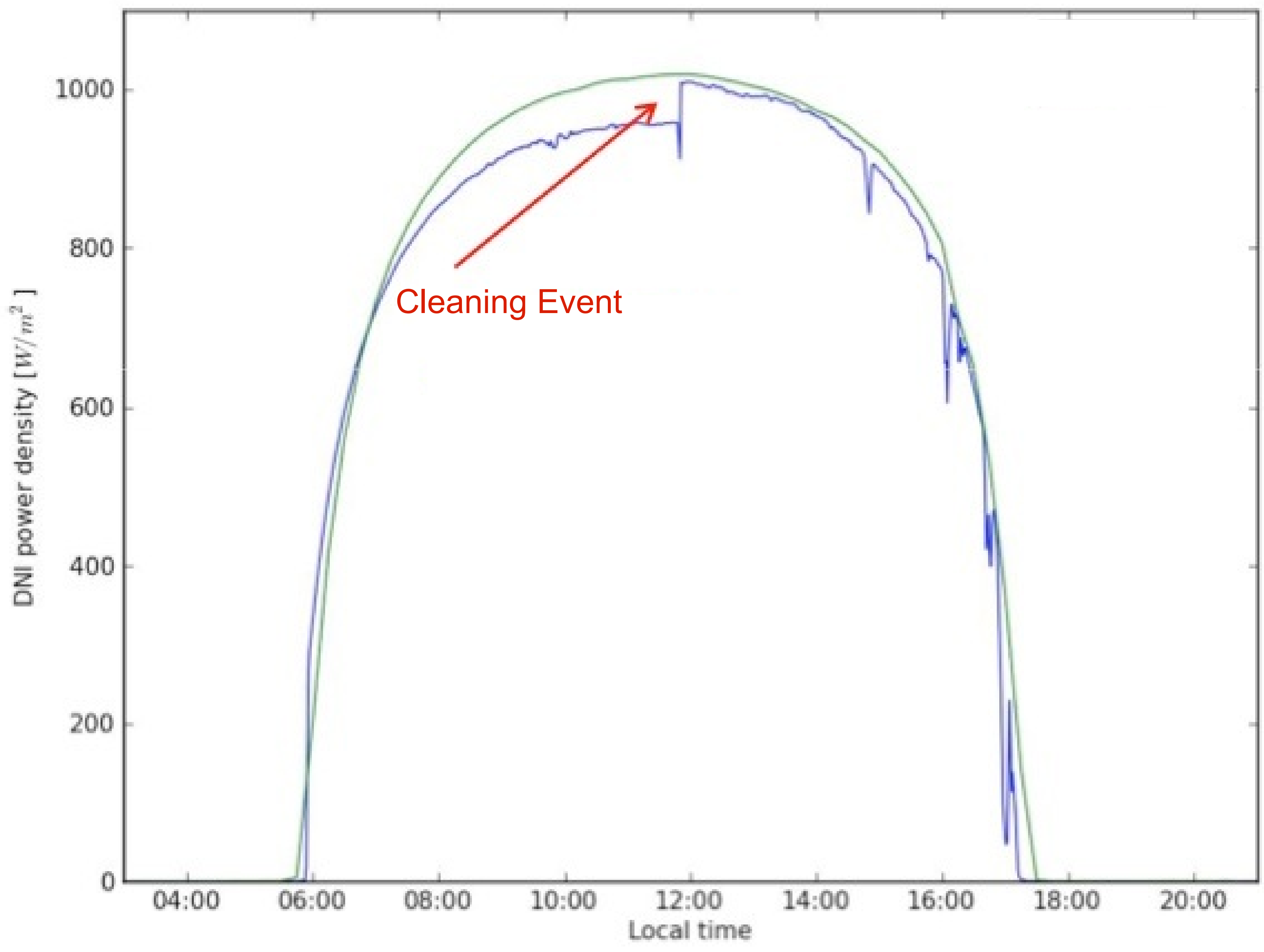
Siting Considerations: Albedo and Reflections

- Albedo is critical to accurate measured and modeled POA
- Keep inverters, buildings, reflective surfaces out of sensor FOV
- Reflections are hard to predict; must monitor data



Ongoing O&M and Data Review

Defined and frequent cleaning and leveling
Biennial service and pyranometer calibrations
Daily automated analysis and plotting scripts
Correlate data with cleaning events
Compare redundant sensors and/or component sum values
Evaluate symmetry of irradiance curves
Compare clear sky transmittance indices (NREL SERI QC)



Cleaning Event
DNI power density [W/m^2]
1000
800
600
400
200
0
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
Local time

Ambient Temperature

Prevalent specification is passive gill ambient temperature shield

Maximum of 10℃ discrepancy between passive and active methods

Lin et al., 2001; Huwald et al., 2009

Impact of +/-10℃ temperature offset on power estimates?

Utah Climate Center

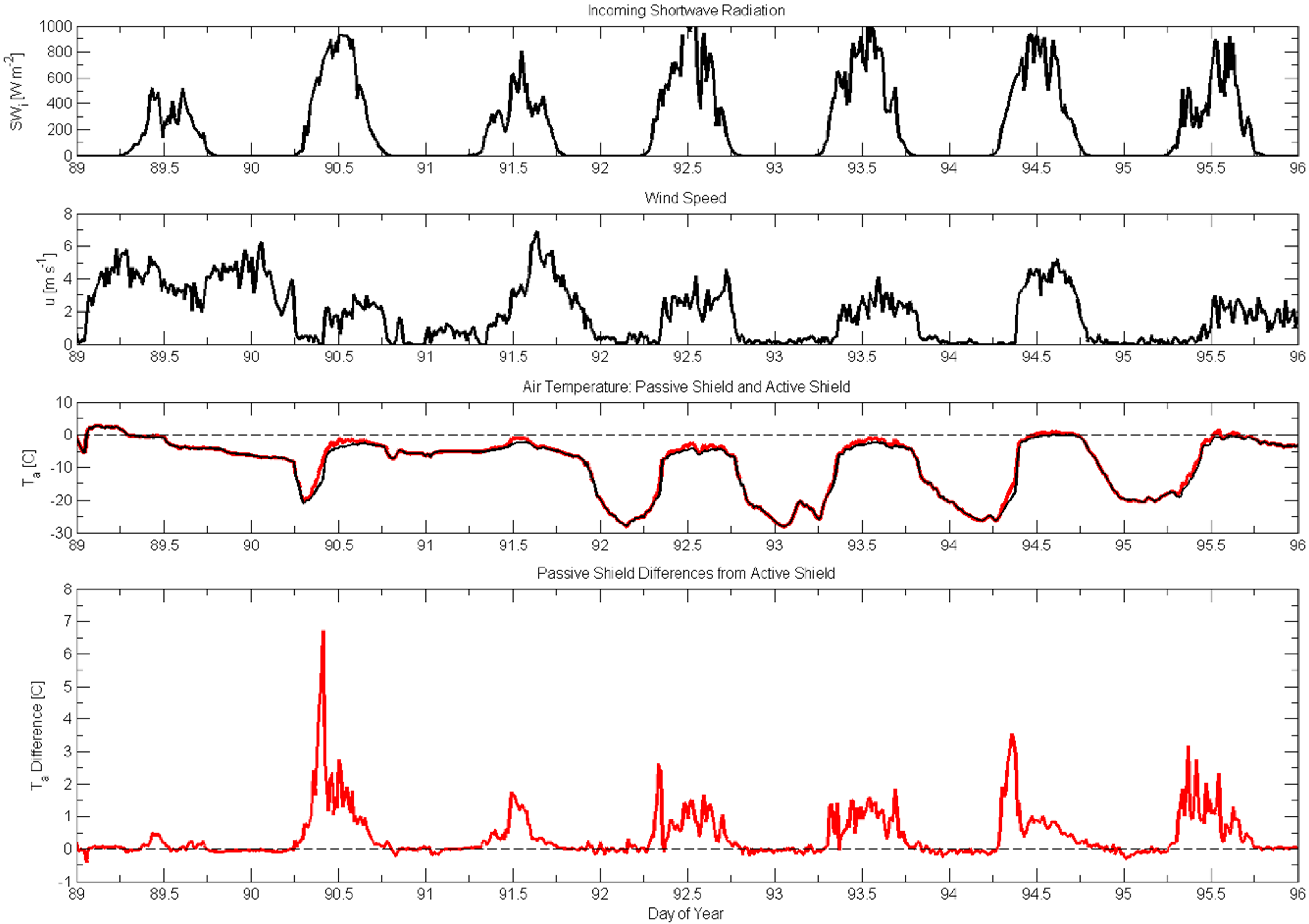
High Albedo Ambient Temperature: Peter's Sinks

15 Min Mean ambient temperature study

February 2013 through October 2014

One ventilated shield versus one 6-plate passive shield

Low thermal mass sensor design (0.1℃ accuracy)



Apogee Instruments

Campbell Scientific Inc.

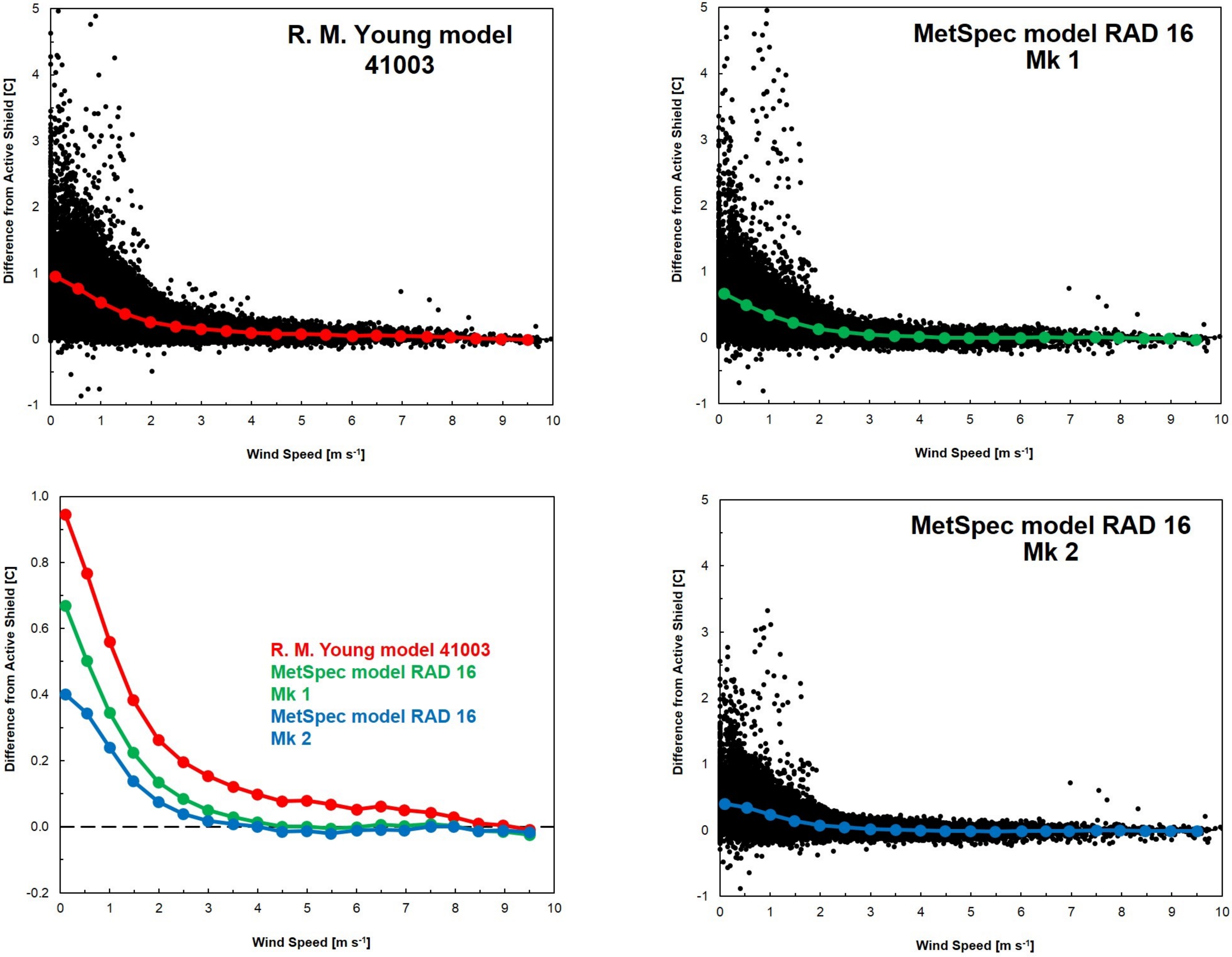
Ambient Temperature: Logan, UT

5 Min Mean ambient temp study

September 2013 to present

Two ventilated shields, six 10-plate passive shields

Low thermal mass sensor design (0.2℃ Accuracy)


R. M. Young model 41003
MetSpec model RAD 16 Mk 1
MetSpec model RAD 16 Mk 2
R. M. Young model 41003
MetSpec model RAD 16
Mk 1
MetSpec model RAD 16
Mk 2
Difference from Active Shield [C]
Wind Speed [m s-1]

MetSpec

Ambient Temperature: Shield Design Improvements

- Enlarged internal space
- Double louver plates
- Black internal louver
- Significant improvement over “Gill” style

GroundWork

Thanks!


CAUTION
GroundWork

LI-COR Biosciences

Sensor Calibration: Standards

ISO 9847, ASTM E824 — Calibration Using Pyranometer

ISO 9846, ASTM G167 — Calibration Using Pyrheliometer

ISO 17025 — General Calibration Laboratory Requirements

Published Expanded Calibration Uncertainties

Sensor Calibration: Indoor

Typical solar applications

Traceable, standardized, quantifiable

Low cost and quick turnaround

Manufacturer credibility and coincident repairs

No time of year limitations

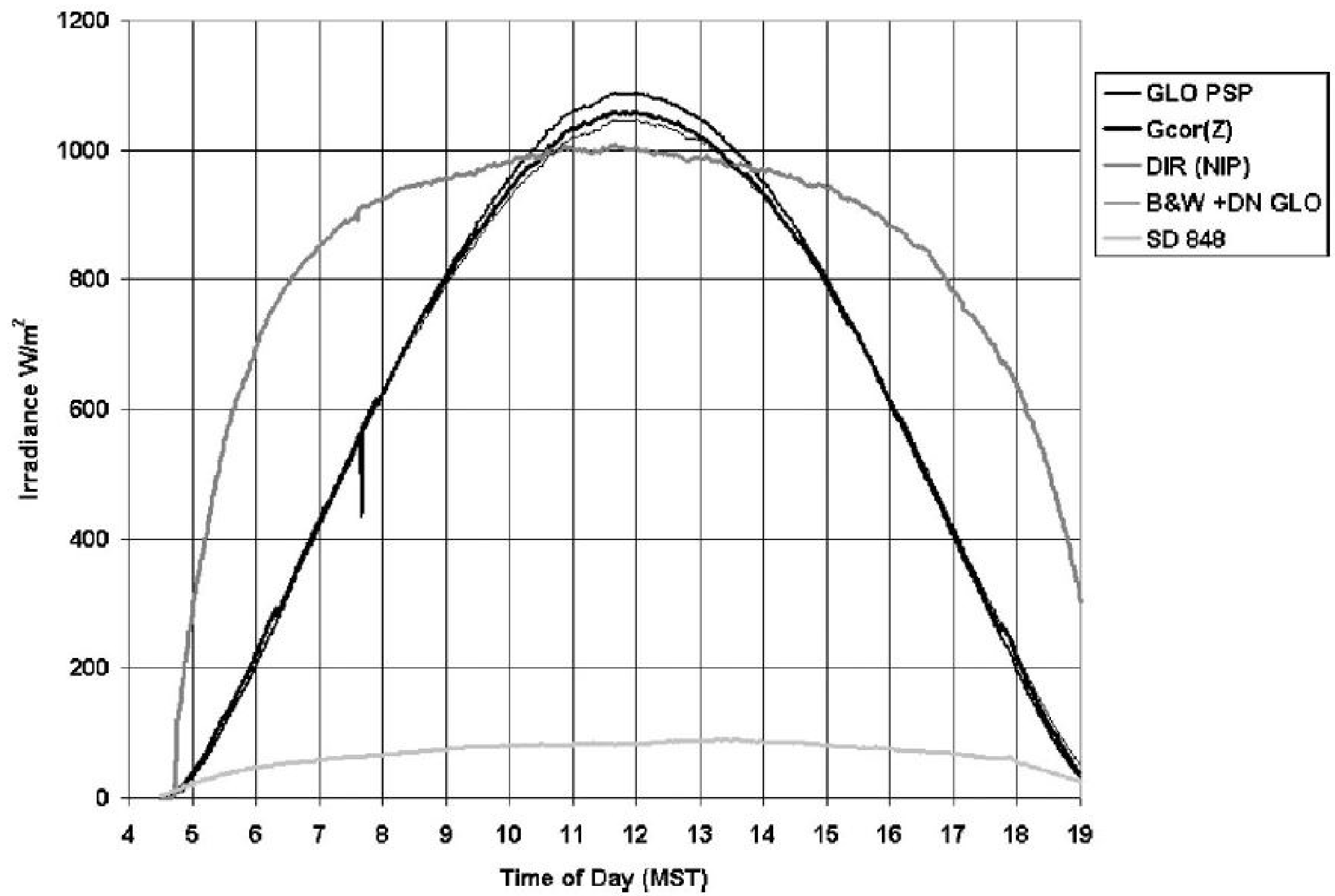
Non-ideal spectral distribution

Various bulb types

Normal incidence calibration

Sensor Calibration: Outdoor

- Typical solar applications, testing, research
- Traceable, standardized, quantifiable
- Ideal spectral distribution
- Calibrate at any deployment angle
- Typically 3rd party
- Calibration season limitations
- Higher cost and slower turn around



Myers et al., 2002

Sensor Calibration: NREL BORCAL

Transfer standards, research

Traceable, standardized, quantifiable

Ideal spectral distribution

Characterization full zenith 80° to 80°

Calibration function

Restricted calibration season

Higher cost and slow turn around